



**ARC · 2016**

# Lessons Learned from the Advanced Topographic Laser Altimeter System

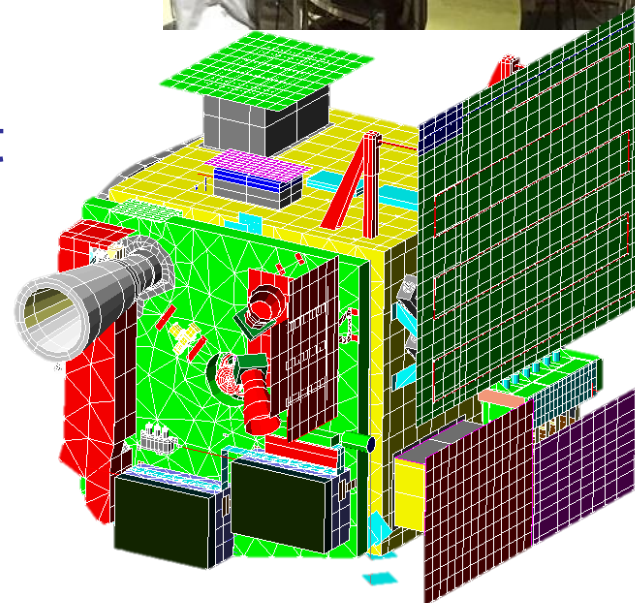
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# ATLAS

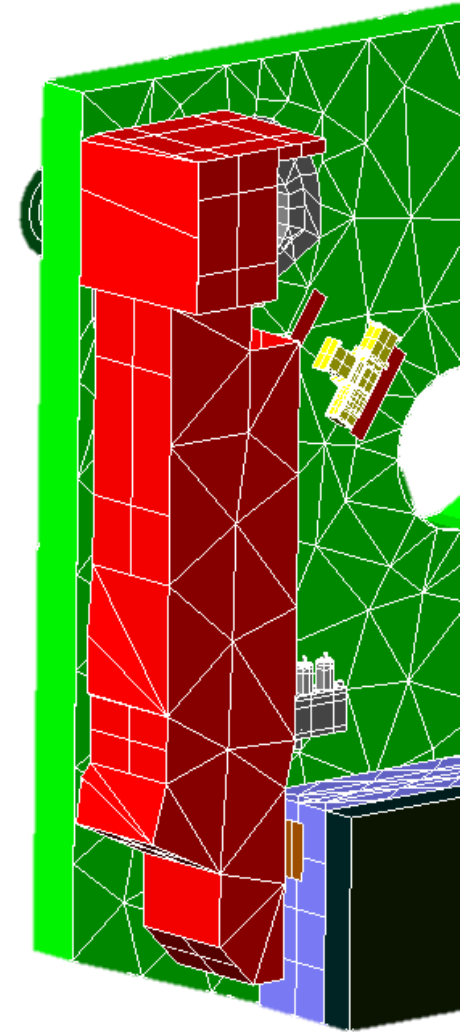
- ATLAS is the primary (only) instrument on ICESat-2
  - Laser altimeter, 6 spots
  - 500km polar orbit, all betas
  - Active boresight alignment
  - Primary thermal goals are ambient temperatures, stability
- Designed, built, and tested at GSFC (2010-2016)
- To be integrated to spacecraft at Orbital-ATK (2016-2017)
- To be launched from Vandenberg (2017)





# Design Lesson Learned 1

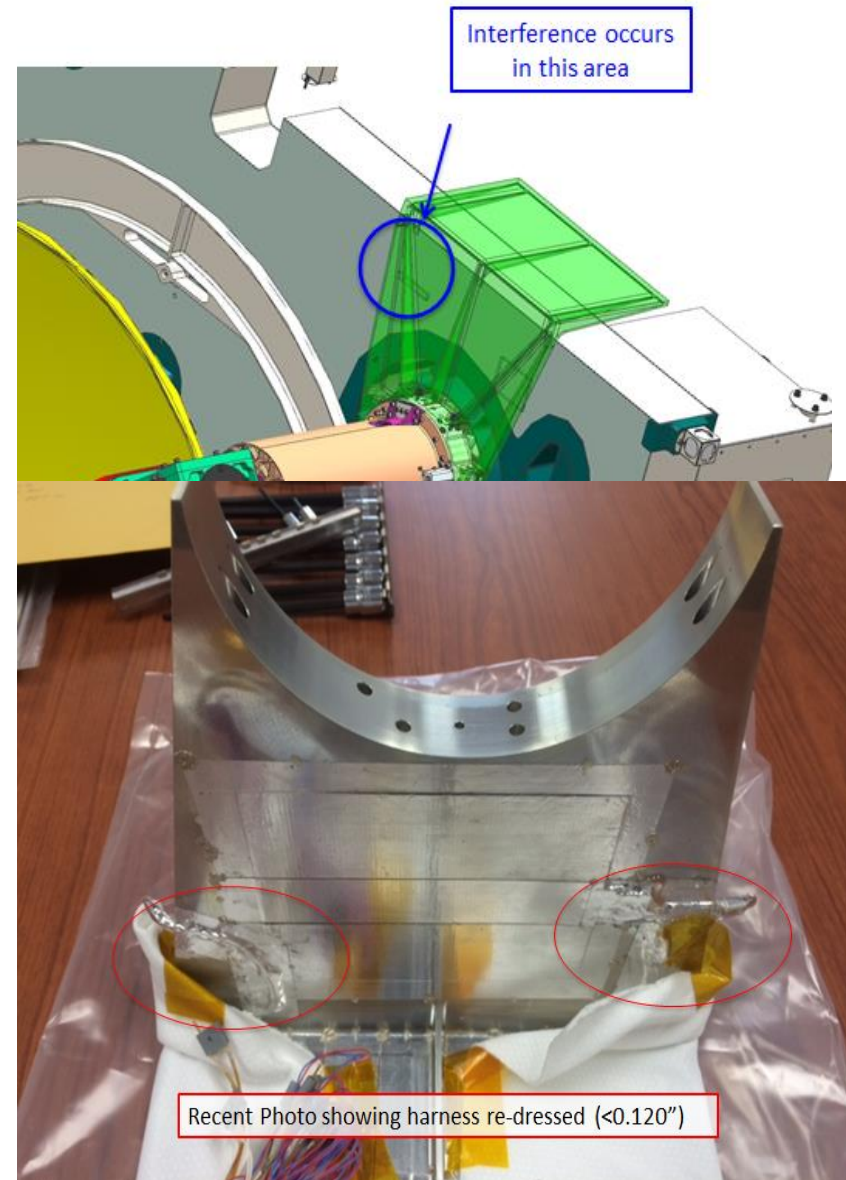
- ATLAS transmitter-to-receiver alignment is 6  $\mu$ Rad (3m from an altitude of 500,000m)
- Between PDR and CDR, optics team struggled to meet these optical requirements with a 0 to 30C temperature range, causing cost over-runs and delays
- Eventually systems allowed thermal to use extra mass and power to create a heated radiative enclosure for the optics, narrowing their temperature range to 15 to 30C. This allowed optics to freeze their design.
- **If you need optical stability, propose a design for thermal stability first**





# Design Lesson Learned 2

- One ATLAS radiator had tight clearances to the primary structure with a heater on the structure-facing surface
- Heaters and associated wiring are generally not included in CAD model
- Nobody recognized that we had an interference until the radiator was installed; heater wires caused an interference and had to be reworked while the rest of the team stood down
- When clearances are tight, make sure to include thermal hardware (including wires) in CAD model





## Design Lesson Learned 3

- ATLAS includes temperature-tuned optical filters (etalons) that require tight control ( $\sim 45^{\circ}\text{C}$ ,  $\pm 0.3^{\circ}\text{C}$  precision) and thermal stability on orbit. When etalons aren't at the right temperature, laser light can't reach detectors.
- Etalons are heavy, isolated, and have small heaters
- Small heaters are too weak to overcome convection; we have to use both A- and B-side heaters when operating in the clean room
- Even with both heaters on at the same time, OFAs take  $\sim 3$  hours to warm up and stabilize every time we power on ATLAS in the clean room.
- When you have a component that must be temperature-controlled for basic instrument performance, make sure to design for ambient operations as well as flight.





## Design Lesson Learned 4

- PDR design of the Power Distribution Unit included enough telemetry to calculate power dissipation for 4 of the 12 dissipating components on ATLAS
- Worked with PDU lead to add current and voltage sensors to the PDU in order to be able to directly measure power draw for all components
- Test Conductors worked with telemetry system to define pseudo-telemetry points, using current and voltage to calculate power dissipations.
- Calculated power dissipations were vetted
- Before PDR, work with electrical systems to make sure you have enough telemetry to calculate power dissipation for all components you'll need for thermal balance model correlation

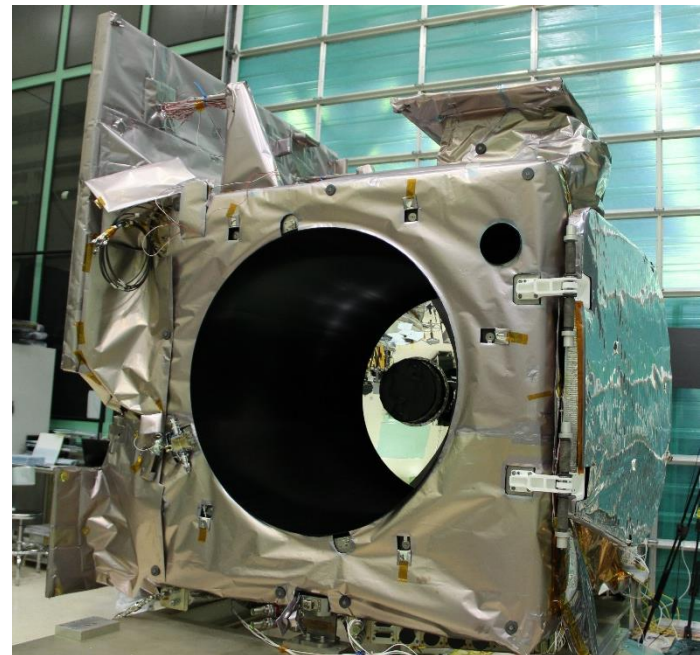


## Design Lesson Learned 5

- Due to surface chagrining requirements, all of the outer layer of MLI had to be electrically dissipative. This drove the design from Kapton to Stamet. Stamet is more expensive, degrades faster, and more fragile than Kapton.
- If an argument can be made early on in the project of why not to use Stamet, it should be pursued.



TIRS (EOS, LEO, launched 2013)



ATLAS (2018 launch, EOS, LEO)



# Design Lesson Learned 6

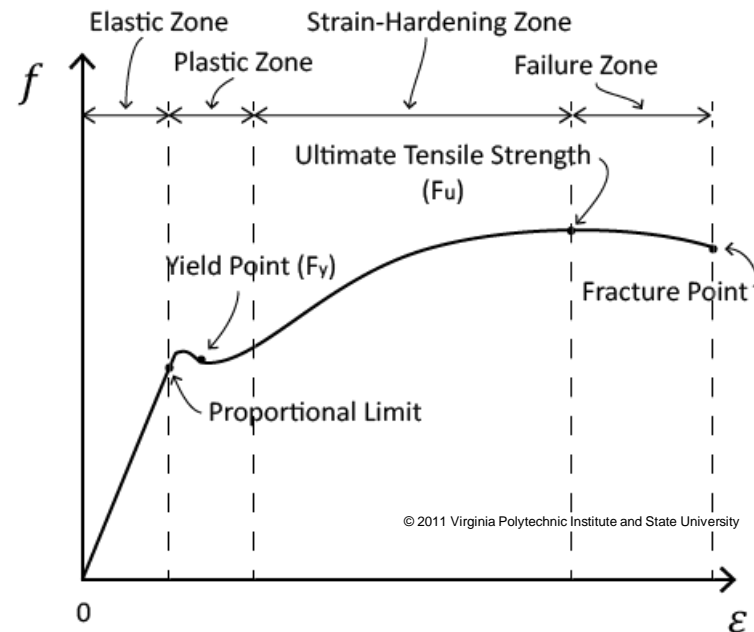
- Problem:
  - The telescope requires tight temperature ( $\pm 0.5^{\circ}\text{C}$ ) control while ATLAS is operational
  - The telescope will see a wide range of temperature throughout orbit.
- Solution:
  - Components that will see a changing environment on orbit require different set of heater setpoints as the seasons progress.
- Design for flexibility with software-controlled heaters





# Analysis Lesson Learned 1

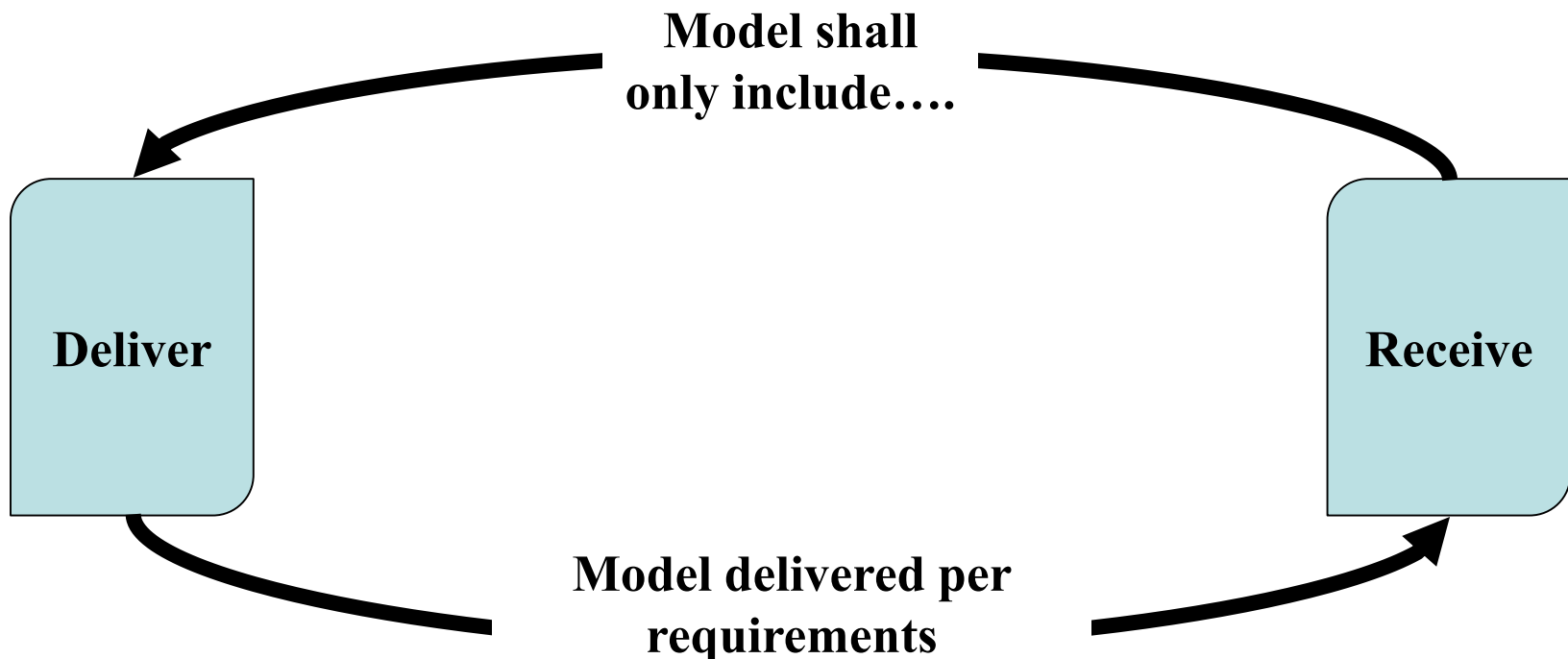
- The structural analysis report from the vendor showed that everything was fine and the designed radiator would survive the load requirement. Upon investigation, it out their model used an incorrect Young's modulus. When we ended up remodeling their radiator, it turned out that it would be too weak for our vibe environment and we had to scrap it.
- **Verify models, not just model reports (even if it means making your own model)**





## Analysis Lesson Learned 2

- We had one small component that used over 80 symbols, one piece of GSE that existed on over a dozen CAD layers with a handful of meshers (some released, some not), etc. It forced the analyst to do a lot of reworking.
- **Provide clear guidance on “style” when getting models from other analysts**





## Analysis Lesson Learned 3

- Once a subsystem delivered their product for integration onto ATLAS, thermal lead and analyst sat with each subsystem to verify the thermal model. This included making sure the physical model looks correct (within reasonable tolerances) as well as making sure power values being used were correct.
- Re-verification of heat loads applied was done when the instrument went under multiple CPTs (Comprehensive Performance Test) during in-air testing.
- This reduced the likelihood of having a model with low reliability when predicting component temperatures for the Instrument TVAC.



## Analysis Lesson Learned 3

- Saving a model with physical changes vs. symbol or logic changes
  - If there are changes to the geometry of the model, it is best to “Save As” new revision.
  - If the model has logic changes or symbol changes, it is best to make note of the changes and not make a new revision.
- What is one of the ways to track logic/symbol changes?
  - Utilize PowerPoint to track symbol/logic changes
  - Make use of the notes section to add thoughts that provides additional context to the slide.
  - Incorporate critical symbols (heatloads, stow/deploy, setpoints..etc) into the case set manager

**Always note down a change made to the model with date stamp.**

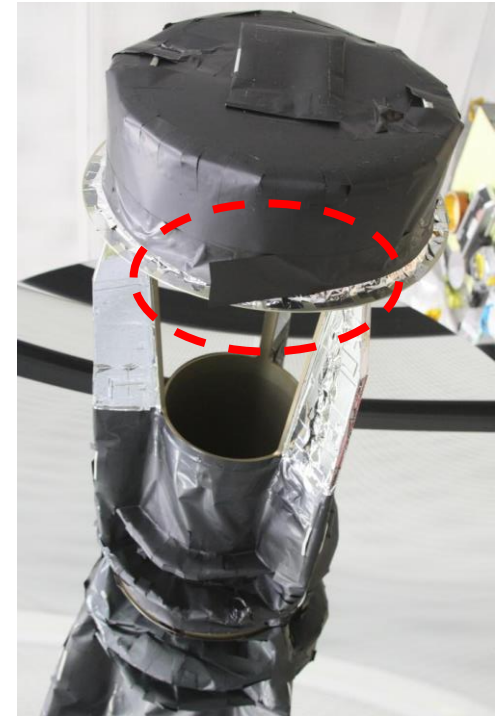
**Change the “autosave” setting in the modeling software such that the work is saved every 10 minutes\***

**\*If the model is substantially large then the autosave setting should be adjusted accordingly.**



# Hardware Lesson Learned 1

- ATLAS requirements constrained MLI tape:
  - Atomic oxygen erosion forced thicker films, especially in optically-sensitive areas that required black outer layer for stray light suppression, which increased stiffness
  - Surface charging forced conductive adhesive, which is less adhesive than the standard Y966
  - Stiff film + weak adhesive = tape lifting, especially around edges and curves
- Returned to blanketing a few days after installation to repair tape lifts with epoxy or replace film with homemade striped tape (alternating conductive and non-conductive adhesive)
- When forced to use unfamiliar tape designs, mock up physical hardware to get familiar with handling prior to flight installation







## Hardware Lesson Learned 2

- QA specified high-strength leads for all flight Kapton film heaters (an option for Tayco heaters)
- High-strength leads are stiffer than standard wires. Without careful forming, then can impart significant loads into the heater.
- After harnessing work was complete, multiple heater had lifted slightly near the leads. The harness team had to rework those leads, and the lifted area had to be epoxied down.
- **Avoid high-strength and thick wires for heaters unless necessary**



## Hardware Lesson Learned 3

- ATLAS had 28 instances of thermostats being bonded onto anodic titanium structures that see significant temperature cycles (-20C to +65C)
- After cycling and vibe, 2 of the thermostats had debonded (the high-strength heater wires didn't help either). This led to a materials engineering research program, then repairing the 2 failed bonds and strengthening the remaining 26.
- Around PDR, work with materials group to demonstrate bonding techniques for any off-nominal thermal joints



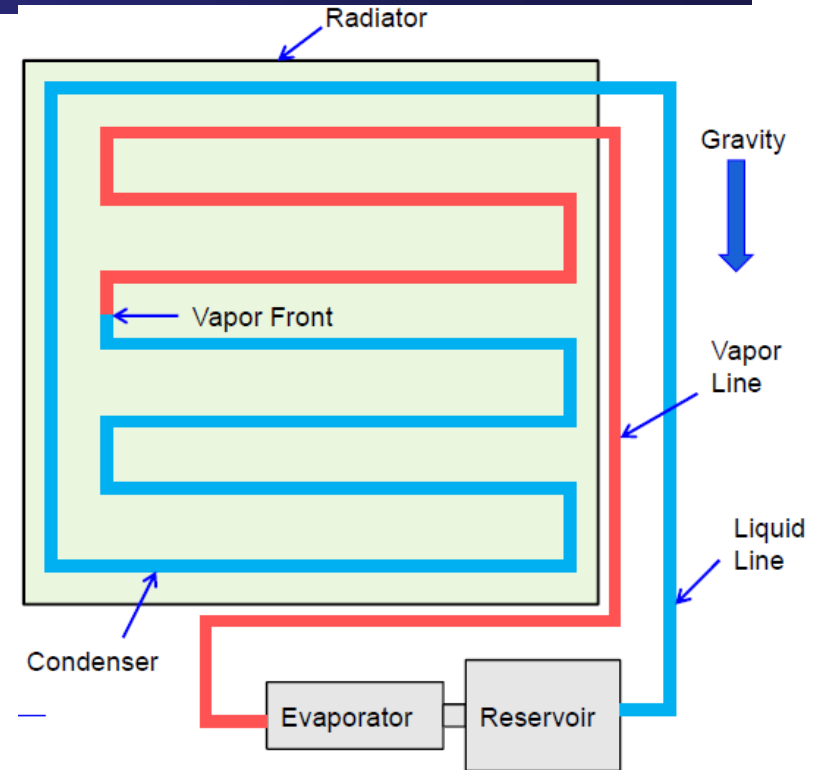
## Hardware Lesson Learned 4

- Thermal group delivered a ground cooling system (GCS), a pumped water system to cool the lasers through heat exchangers
- After qualification testing and installation on the instrument, one of the fittings between a heat exchanger and transport line sprung a small leak
- Pressurized pipes and fittings – we went to the GSFC Propulsion Branch to ask their advice. They quickly pointed out that the swage fittings and aluminum heat exchanger tubes were incompatible, which they could have told us a year before if we'd come to them then
- When working with hardware that is outside of your group's specialty, get input or direct assistance from other groups that work with similar types of systems.



# Testing Lesson Learned 1

- The ATLAS LHP operates in reflux (radiator above evaporator)
- In component TVac test, a combination of gravity and the control heater power on the reservoir caused flow oscillations, transferring control heat directly from the reservoir to the radiator. This was a surprise to the in-house LHP expert and the LHP vendors



- Had to retest horizontally, then add GSE heaters to maintain control while vertical (required for ATLAS and spacecraft TVac)
- Details are in a Spacecraft Thermal Control Workshop presentation by Jentung Ku (NASA GSFC, March 2014)
- **While designing LHPs, be aware of this gravity affect**



## Testing Lesson Learned 2

- Structural/optical modeling showed that ATLAS alignment is sensitive to jitter from the spacecraft
- The TVac chamber was run empty with accelerometers on the chamber floor. The results were input to the jitter model, and the results showed that we would not maintain alignment in TVac due to mechanical noise.
- Mechanical team developed and verified a Jitter Isolation System for use in ATLAS TVac testing
- If you're sensitive to jitter on the spacecraft, you might be sensitive to jitter from the TVac chamber too

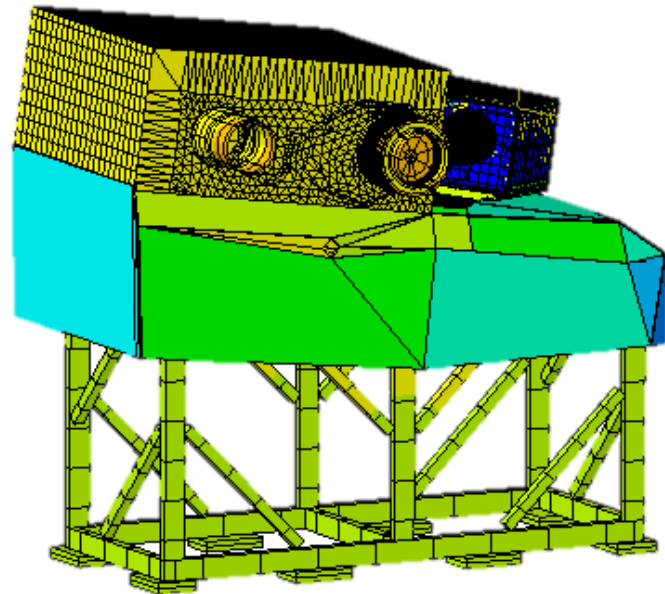
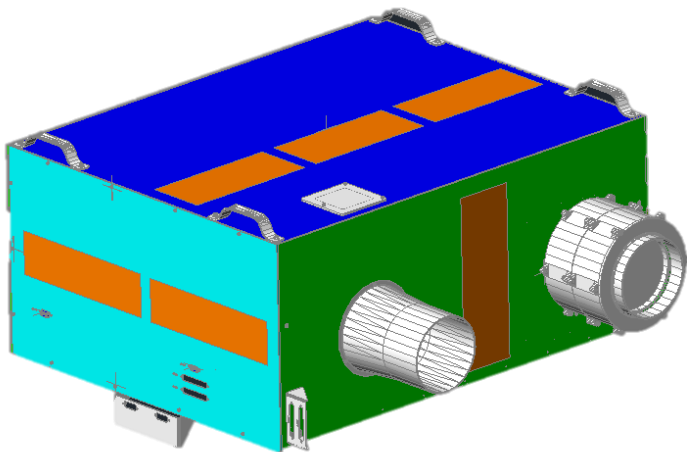






# Testing Lesson Learned 3

- ATLAS has very tight alignment requirements (3m over 500km), driving the need for a stable thermal design with plenty of control authority
- GSE is needed to verify that alignment in TVac
- In order to measure this, the GSE needs to have better optical stability than the flight hardware, needing a more stable thermal design with even more control authority
- If your verification includes precise GSE in your TVac test, pay close attention to its thermal requirements and design early





# Conclusions

- ATLAS passed all environmental testing at GSFC and is ready to be shipped to the spacecraft vendor for integration
- If we ever get an ICESat-3, we will try to repeat no more than half of these mistakes, in addition to a bunch of new ones